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[0001] METHOD AND SYSTEM FOR IMPLEMENTING SMART ANTENNAS AND DIVERSITY TECHNIQUES

[0002] CROSS REFERENCE TO RELATED APPLICATIONS

[0003] This application is a divisional application of U.S. application no. 10/328,663 filed on December 23, 2002, which claims priority from U.S. provisional application no. 60/363,051 filed on March 8, 2002, which are incorporated by reference as if fully set forth.

[0004] FIELD OF THE INVENTION

[0005] The present invention relates to wireless technology. More particularly, the present invention relates to the field of smart antennas and diversity techniques for improving the quality of the transmitted and/or received communication to facilitate selection of the better quality signal.

[0006] BACKGROUND

[0007] Transmitters and receivers of wireless systems typically employ a single antenna which may be preferred from a cost viewpoint. However, multiple antenna arrays have also been employed which have been found to provide certain cost/benefit features. It is nevertheless highly desirable to provide a capability of selecting the antenna receiving (or in the alternative transmitting) the signal having the best quality.

[0008] SUMMARY

[0009] The present invention is characterized by providing techniques and apparatus including a channel estimator for monitoring signals received by each antenna in a multi-antenna array to determine signal quality, and to select the better quality signal for processing. Monitoring of signal quality continues

throughout the reception period in order to provide the capability of altering the selection of the signal chosen for processing whenever such a change is again warranted. Some of the techniques described herein are usable for both uplink and downlink applications.

[0010] BRIEF DESCRIPTION OF THE FIGURES

[0011] The following figures are useful in describing the techniques and apparatus embodying the principles of the present invention in which like elements are designated by like numerals and, wherein:

[0012] Figure 1 is a simplified schematic showing one preferred embodiment of a multiple antenna system embodying the principles of the present invention.

[0013] Figures 2 through 5 are simplified diagrams showing further alternative embodiments of the present invention.

[0014] DETAILED DESCRIPTION AND PREFERRED EMBODIMENTS THEREOF

[0015] Figure 1 shows a receiver facility 10 comprised of antennas 12 and 14, each receiving an incoming RF signal from a remote transmitter, not shown. The signals received by antennas 12 and 14 are respectively amplified at 16 and 18 by linear low noise amplifiers and are then respectively delivered to mixers 20 and 22 where they are multiplied by low frequency components, which could be 0, 1, -1, or a continuous wave source with a period equal to a symbol (e.g. 240 kHz for WTDD)

[0016] In the example shown in Figure 1, the symbol rate for a code division multiple access (CDMA) based system is 240kHz and, after despreading the signals derived from the multiple antennas they can be separated. It should be noted that other frequencies which can achieve the same effect may be selected.

[0017] Circuits 24 and 26 respectively provide the support signals for the incoming signals and are driven by source 28 which in the example given, operates at 240kHz. The signals from mixers 20, 22 are combined at 30 to provide the

possible outputs as shown. The outputs are then sent to a single receiver for further processing.

[0018] It should be noted that the antennas employed may be similar to one another and placed at different locations or may be of different designs. The resulting signals are compared to determine their quality and selected to obtain the best quality signal. Also, more than two antennas may be employed.

[0019] Figure 2 shows another alternative embodiment 32 of the present invention in which antennas A and B, which may be used either for uplink or downlink applications, are coupled through switch means 34 which may preferably be electronic switching means for coupling to the selected antenna for transmission purposes, or for coupling the selected antenna to an input of a receiver for reception purposes. In a downlink example, the receiver processes a sequence of timeslots or a sequence of frames from one antenna and another number of units from the remaining antenna(s). Although only two antennas are shown in Figure 2, it should be understood that a greater number of antennas may be employed.

[0020] As an initial operation, the output signal is coupled to monitoring device 36, shown in Figure 3. Assuming that the quality of the signals A and B are substantially equal, monitoring circuit 36 operates switching means 34 to alternate so that the frames or slots received are alternately transferred to the output utilization device as shown by waveform 38a. As another example, the alternating switching arrangement may be two (or more) consecutive time slots of signal A alternating with an equal number of time slots of signal B.

[0021] Assuming that the frame or slot of each of the signals A and B being examined indicate that the quality of the signal A is superior to that of the signal B, as a result, the monitoring means 36 operates switch means 34 in such a manner as to receive three units (i.e. time slots, frames, etc.) of signal A in succession and thereafter switch to antenna 14 to receive one unit of signal B, and thereafter repeating this pattern. Throughout this signal selection, the monitoring circuit 36 continues to monitor the slots/frames of each signal A and B and, in the event that

there is a change in signal quality, whereupon the quality of signal B is superior to that of signal A, monitoring means 36 operates switch means 34 so as to couple a greater number of consecutive units of signal B to the output utilization device and thereafter a lesser number of consecutive units of signal A, repeating this pattern until another change in signal quality occurs between the signals A and B. Again, it should be noted that monitoring of signals A and B continues throughout the reception period (or transmission) to continually ascertain the quality of the signals A and B and to alter the weighting of the intervals per antenna coupled to the receiver.

[0022] Although the example given shows a 3-to-1 ratio of signal reception intervals favoring signal A as shown by waveform 38b or favoring signal B, shown by waveform 38c, it should be understood that other weightings may be selected and such weightings may be selected as a function of relative quality. For example, one relative quality level may warrant a 4-to-1 ratio, a lower relative quality level may warrant a 3-to-1 ratio, a still lower quality level may warrant a 2-to-1 ratio, and so forth. The antennas 12 and 14 employed may be similar in design and distinguished merely by physical location; or may be antennas of different designs. For example, both antennas may be omni-directional, one antenna may be omni-directional and the other have a highly directional radiation pattern, and so forth. Each antenna may alternatively be an antenna array, the arrays having different directivity patterns, similar directivity patterns but with dissimilar orientations, and so forth.

[0023] The number of antennas switched may be greater in number than two. However, monitoring and comparison of the A and B signals and another signal or signals continues regardless of the priority given, whereupon a change in signal quality as between the signals monitored will cause an appropriate change in the priority. It should be noted that when signal quality as between the monitored signals is equal, an alternating pattern as shown by waveform 38a is obtained. Equality may be provided employing other patterns as well. For example, two

intervals or frames of signal A may alternate with two intervals or frames of signal B.

[0024] The arrangement of the embodiment shown in Figures 2 and 3 is simple to implement and cost of implementation is minimal.

[0025] The same technique may be used for uplink application, especially for time division duplex (TDD) systems. Since uplink and downlink channels are reciprocal in TDD, once signal quality is measured at each antenna, this information is utilized to decide which antenna is given priority and in a similar fashion to that of the reception application, a transmitter transmits multiple units from one antenna and another different number of units from the other antenna based on comparison of their signal qualities. The transmitter facility may provide a pilot signal to remote receivers, over each antenna

[0026] Figure 4 shows another alternative embodiment of the present invention and a modification of that shown in Figure 2. In the embodiment 32 of Figure 2, measurements are made over the whole time slot, and a decision based on these measurements is utilized in the next subsequent time slot or frame. To significantly reduce the delay in initiating priority of the compared signals, the embodiment 32' shown in Figure 3 performs measurements at the beginning of a time slot or frame by examining only one or a few symbols. To accomplish this, the receiver learns the correlation between measured quality in a first bit or symbol or several bits or symbols and the rest of the time slot or frame. This is accomplished, for example, by calculating and storing in a memory the energy per symbol of the first symbol(s) to compare this with the energy per symbol of the remainder of the time slot, and the block error of the time slot and building a correlation model, which will be used for the real time measurements. The technique of Figure 4 is preferable to the technique shown in Figure 2 when faster changing channels are encountered.

[0027] In TDD applications, the correlation between the first bit(s) energy and channel quality is determined, shown by waveform 40a. (In case of frequency

division duplex applications, the monitoring device learns the correlation between a short segment of the pilot energy or other parameters and the channel quality). As shown by waveform 40b, one or two symbols of signal A are analyzed followed by an analysis of one or two symbols of signal B and, immediately thereafter, the remainder of the time slot or frame is derived from the selected antenna 12 or 14 in accordance with the quality levels of the signals A and B.

[0028] The first one or two signals utilized for quality measurements and comparisons may be reconstructed through the utilization of error correcting codes or the like.

[0029] Figure 5 shows still another embodiment of the present invention in which techniques of the previous embodiments are combined to reap the benefits of each technique as channel conditions warrant. Although the technique necessitates a greater amount of processing, more optimal solutions are available.

[0030] In the embodiment 44 shown in Figure 5, channel estimator 46 estimates channel response and changes the weights of the algorithms of 48 and 50 (block 48 deploys the algorithm 32 and block 50 uses algorithm 32') depending upon the channel properties (e.g. for fast changing channels 32' will be used more often, for slow changing channels 32 will be used more often).

[0031] In still another embodiment of the present invention, in third generation (3G) systems of the TDD and FDD types, there is a need for single quality measurements in order to make decisions regarding various processes. In the present invention, one example is a selection of a signal from one of the antennas to process for receive and transmit diversity. The desired measurement is typically related to signal-to-noise ratio which may be inferred from signal measurements. The present concept provides the ability to make decisions based on noise level when nothing else is known about the signal. As one example, broadband signal level is measured from the multiple antennas to decide among the antennas, such as antennas 12, 14 of Figure 1, which one has the stronger signal. In the event that there is no way to know if the signal measured is due to desired

signal or interference, the noise energy in a guard period is measured and then the energy per bit is measured for each antenna in order to select the antenna with the highest energy per bit to the noise energy ratio in order to select the antenna with the highest signal to noise ratio. Thus, the guard period (no signal) received by each antenna A and B is alternately measured in order to give priority to the desired signal. As another alternative, measurements may be performed during the intervals between the transmission of data signals, and analyzing in order to determine which signal to give priority. The priority may then be weighted in the matter described here and above such as the example shown in Figure 2.

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